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MACHINE CASTING OF FERROUS ALLOYS

SEMI-ANNUAL TECHNICAL REPORT,

ARPA CONTRACT NO. DAAG46-73-C-0111,

August 1973

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By

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Corporate Research and Development
General Electric Company
Schenectady, New York

Sponsored by: Advanced Research Projects Agency
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Effective Date of Contract: February 1, 1973

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Amount of Contract: $148,060

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ON

MACHINE CASTING OF FERROUS ALLOYS

To apply an automated machine casting process which uses reusable metal molds to structural castings of materials, a central problem to be overcome is the lack of soundness associated with die castings. This lack of soundness is due to both solidification shrinkage and to entrainment of gas during injection of metal into the mold.

The general purpose of the first six months' work was to identify techniques which will produce sound castings in reusable chill molds - techniques which are compatible with an automated machine casting process.

To do this, castings made in permanent chill molds were studied initially divorced from any consideration of the type of machine which would produce such castings, since the use of an automated process for structural materials depends on the casting's integrity. The automated machine will have to fit the process.

Permanent molds of two test shapes were constructed. One shape was that of an I-beam, the other that of a blade. Alloys cast included 304 stainless steel; the Ni-base alloys IN-738 and TRW-VIa; and the Co-base alloys MarM302 and MarM509.

Initial work indicates that ceramic inserts markedly improve the soundness of chill castings. Inserts are used to direct heat flow to allow feeding of the casting. They are also used to reduce hot tearing and cracking, due to mold-casting mechanical interactions.

Casting integrity is also a sensitive function of alloy type. Casting with long freezing ranges have large amounts of microporosity, while those with short freezing ranges have little. Mechanical testing confirms this difference, with a chill-cast, short-freezing-range alloy having comparable stress rupture behavior to the investment cast alloy; while a chill-cast, long-freezing range alloy has degraded properties.

The work to date on obtaining integrity in permanent, rapidly solidified castings has shown three things: there is a need for thermal conditions to allow adequate feeding of solidification shrinkage; certain alloy types respond better to a rapid solidification process; and the quality of the surface finish strongly depends on mold coating.

In a normal die casting process, where the in-gates are narrow, the thin gate area freezes soon after solidification starts. Then the metal in the die cavity has no source from which to feed its shrinkage. To assure

adequate feeding with an all-metal mold and gate system, the gate would have to be quite large. For the gate to simply remain molten during the time the casting is solidifying, the gate would have to be as large as the thickest section of the casting. However, even a molten gate does not assure adequate feeding if, for example, the thickest section of the casting is separated from the gate by a thinner casting section. In order to assure feeding in such a case, the gate must also supply heat to the thin casting section so that the solidification front moves toward the gates. The size of a gate to do this in an all-metal mold could easily become quite large, increasing not only scrap losses, but also mold and finishing costs. The use of a ceramic insert in a gating section reduces this size needed. The insert can hold sufficient heat to set up a desired thermal gradient in the casting.

In an automated machine casting process, such as insert will be automatically placed in a mold, a casting made, and the insert ejected with the casting. Inserts need only be off-the-shelf ceramic tubes which fit the gate. The ceramic need not be disposable. If the ceramic is such that it can take thermal shock and the wear of the rapidly flowing metal, it could be a permanent part of the mold.

Alloy type appears to be quite important in obtaining sound structure. Mar M 302 has shown low levels of porosity and good properties in permanent mold castings, while both TRW VI A and IN-738 have certain amounts of microporosity and degraded properties. The microstructure of TRW VI A indicates that the last liquid to freeze, near the γ-γ' eutectic, is isolated from the main pool of liquid. In such a case, there is no feeding and a small pore is left. In Mar M 302, the Co dendrites are a smaller fraction of the microstructure than are the Ni dendrites in TRW VI A or IN-738. The interdendritic liquid which freezes in Mar M 302 has much easier channels to feed.

This should be a general case, that alloys with long freezing ranges, with a gradual decrease in liquid with temperature tend to have a more severe microporosity problem than those which freeze over a more narrow temperature range. The high freezing rate and high gradient reduce the physical length of the liquid to solid zone in the casting. This would tend to help most materials with very short freezing ranges.

Surface finish has been greatly improved by use of a more insulative mold coating. To avoid entrainment of gas, mold filling rates have been less than in a die casting process. This slower filling rate results in a tendency for the metal to freeze irregularly on the surface. A coating which allows the metal to form against the mold can reduce this. What is required in the coating is that its surface heat rapidly and hold that heat for a short period of time, keeping the metal molten. In addition, the coating must not release gasses to get into the melt as the rapid rate of freezing is such that the bubbles can't rise out of the casting, but are trapped near the surface.

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